

Rock of Ages, or Ages of Rocks

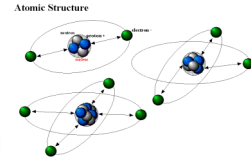


How do we know a Moon rock is 4.2 Gyr old (for example?)

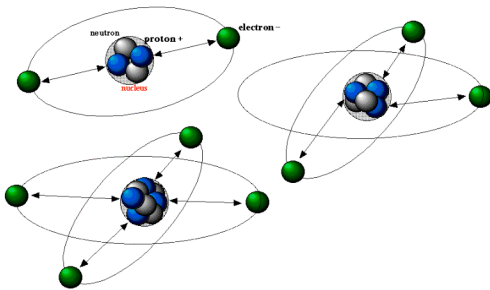
See section 7.4 for content

Age of formation of rocks is determined by radioisotope dating

- "all matter is composed of atoms"
- Atoms are composed of nuclei and electrons
- Almost all of the mass (all except about 1 part in 2000) is contained in the nucleus
- The nucleus is incredibly small (~1-10E-15m)
- Nuclei are composed of two types of particles, protons (positive charge) and neutrons (electrically neutral)

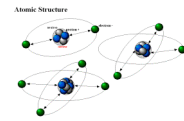


Atomic Structure



The world of atomic nuclei

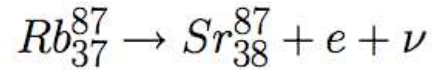
- The construction of an atomic nucleus is indicated by its symbol, such as ${}_{7}^{14}\text{N}$ or ${}_{7}^{13}\text{N}$.
- The lower number is the number of protons (atomic number), and determines the chemistry
- The upper number is the number of protons and neutrons (atomic weight) and determines the nuclear physics.



Radioactivity and radioisotopes

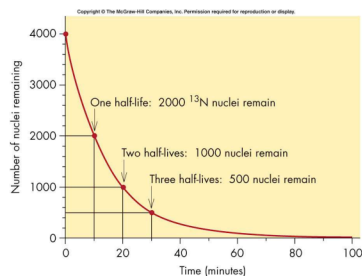
Isotope is the term for different nuclei with the same number of protons (and thus chemistry) but different numbers of neutrons. Some isotopes are stable, meaning they last forever, and some are unstable (radioisotopes) and decay into “daughter nuclei” and radiation.

The radioactive decay of rubidium 87 to strontium 87



Rubidium is selected in formation of minerals in place of potassium. An atom with a rubidium 87 nucleus will decay to strontium 87

How can this be used to date rocks?

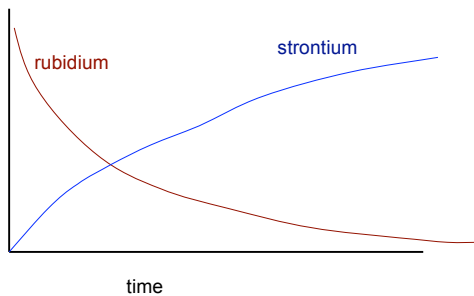


The number of parent nuclei (Rb in this case) declines with time according to a precisely expressed exponential law. For each Rb atom that “disappears”, a strontium atom is formed

The concept of the “half life” of a radioisotope

- The amount of time after which half of the original number of radioisotopes is left.
- Ranges from 10 minutes for Nitrogen 13 to 46 billion years for Rubidium 87
- By comparing the number of “parent nuclei” to “daughter nuclei”, you can determine the amount of time since the parent atoms were trapped in the rock

A simplified version of the idea



How can we be sure there was no Strontium 87 in the rock when it formed?

There would be more present than was produced by radioactive decay, and we would overestimate the age of formation of the rock.



Answer: there is another common isotope of strontium, Strontium 86, which is not the daughter product of radioactive decay. Every Sr86 nucleus that was in the rock when it formed is still there. By measuring the abundance of Sr86, as well as Sr87 and Rb87, we can control for the "affinity" of the mineral for Strontium, and unambiguously obtain the age of formation

With some algebra, you can show that

$$\text{Let } y = \frac{Sr^{87}}{Sr^{86}}, \text{ and } x = \frac{Rb^{87}}{Sr^{86}} \text{ now}$$

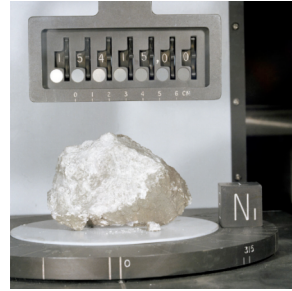
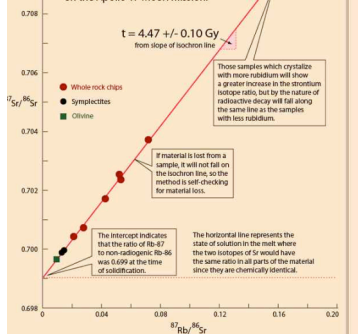
$$\text{and } b = \frac{Sr^{87}}{Sr^{86}} \text{ when rock formed}$$

$$\text{then } y = ax + b \quad (2)$$

where a is uniquely determined by the time since formation of the rock.

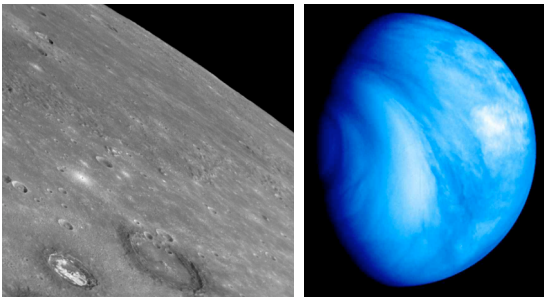
You can then measure x and y for minerals in a present day Moon rock, and plot them up on a graph. They should fall along a straight line (consistency check). If they do, the slope of the line gives the age of formation of the rock.

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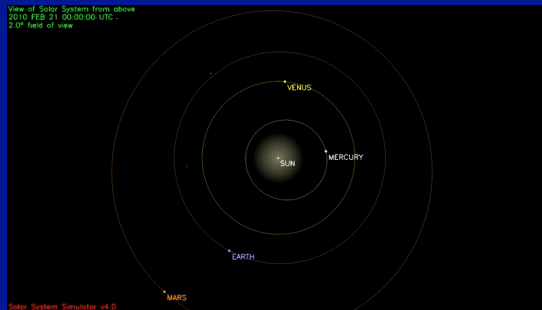
By comparing the numbers of parent and daughter nuclei from the rubidium-strontium system, and other sets of radionuclides, scientists can determine the age of formation of lunar rocks, meteorites, and Mars rocks

Next Topic: Mercury and Venus



We follow the traditional astronomy approach of going out from the Sun

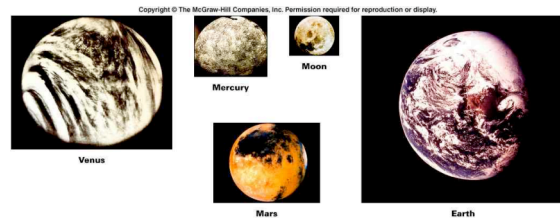
Where are Mercury and Venus in the Solar System?



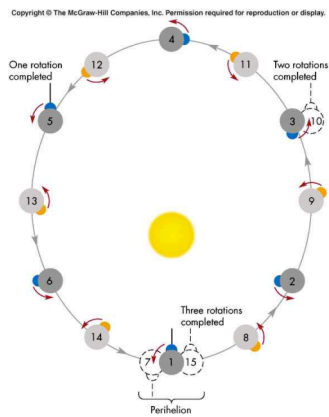
Mercury and Venus in the night sky

- Mercury is always very close to the Sun in the sky, is small in diameter, and is farther away than Venus. This makes it a difficult object to see. The legend is that Copernicus never saw it.
- Venus at times is the brightest object in the sky after the Moon; you can't miss it.

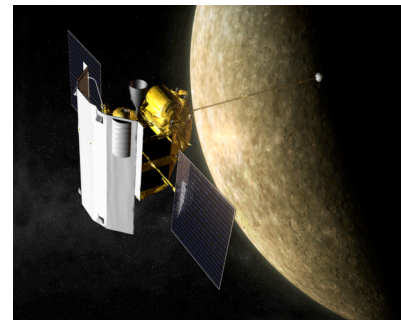
Relative sizes of Mercury and Venus



3/2 synchronous rotation and the weird day of Mercury



The Messenger spacecraft and the study of the planet Mercury



The Messenger Spacecraft: launch and arrival

http://messenger.jhuapl.edu/the_mission/movies.html

The surface of Mercury

